Old Dominion University Research Foundation

Coastal Zone Management Program

Virginia

APPLIED MARINE RESEARCH LABORATORY
COLLEGE OF SCIENCES
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA 23508

WETLANDS MITIGATION PROJECT

A Comparison of a Mitigation Marsh with an Established Marsh in Norfolk, Virginia

An Evaluation of the Invertebrates, Fish and Sediments

By

Dr. David Feigenbaum, Principal Investigator

and

Dr. Donald Swift, Co-Investigator

with an Appendix by Dr. Carvel Blair

Submitted to the

City of Norfolk
Department of Environmental Services
809 City Hall Building
Norfolk, Virginia 23501

May 1989

APPLIED MARINE RESEARCH LABORATORY
COLLEGE OF SCIENCES
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA 23508

WETLANDS MITIGATION PROJECT

A Comparison of a Mitigation Marsh with an Established Marsh in Norfolk, Virginia

An Evaluation of the Invertebrates, Fish and Sediments

By

Dr. David Feigenbaum, Principal Investigator

and

Dr. Donald Swift, Co-Investigator

with an Appendix by Dr. Carvel Blair

Submitted to the

City of Norfolk
Department of Environmental Services
809 City Hall Building
Norfolk, Virginia 23501

Submitted by the

Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508

May 1989

EXECUTIVE SUMMARY

In 1983, the U.S. Navy created a 6.5 acre marsh, known as Monkey Bottom, in its Willoughby Disposal Area, to compensate for marsh previously destroyed in the area by the dumping of dredge spoil. The success of the new marsh was examined by Old Dominion University by comparing sediments, infauna, fish and mobile invertebrates during summer and late fall/winter with those of an established marsh on the nearby Lafayette River, Larchmont Pond Marsh.

Since its construction, the Monkey Bottom Marsh has accumulated 2 - 11 cm (mean = 4 cm) of marsh deposits. However, the comparison marsh is still much richer in organic carbon. The abundance of infauna, fish and mobile invertebrates at Monkey Bottom compared favorably with those at Larchmont Pond. Monkey Bottom sediments were inhabited by three clam species and several families of polychaete worms. Fish utilizing the marsh as a nursery area and/or for forage were two species of mullet, menhaden, spot, silversides and killifish. Blue crabs and grass shrimp were also abundant during the summer sampling. Marsh bird populations, compared by Dr. Blair, also appeared similar among the two marshes. In general, the Monkey Bottom Marsh appears to be healthy and benefiting the coastal zone as a nursery area, a forage area and as an accumulator of organic materials.

TABLE OF CONTENTS

WETLANDS MITIGATION PROJECT

A Comparison of a Mitigation Marsh with an Established Marsh in Norfolk, Virginia.

An Evaluation of the Invertebrates, Fish and Sediments

By

Dr. David Feigenbaum, Principal Investigator

and

Dr. Donald Swift, Co-Investigator

INTRODUCTION

With population rapidly increasing along estuaries, human activity will inevitably have an adverse impact on delicate natural ecosystems present in this coastal zone. Of foremost concern is the potential loss or damage of salt marshes which provide organic enrichment to estuaries and coastal waters and act as nursery areas for many species of fish and invertebratesas well as forage sites for many species including birds. In recent years, a policy of "mitigation" has been applied by state and federal agencies to lessen the impact of human tampering with the environment. With marshes, the policy has often called for the man-made creation of a marsh to replace a destroyed natural marsh. In this, there is a tacit implication of no net environmental loss.

The question is, will it work? As Zedler <u>et al</u>.(in press) suggest, the evaluation of a marsh on is an extremely complex process. In the present study we have limited the question to:

will a man-made marsh "provide" the flora and fauna equivalent to an established marsh? The answer to this question may well depend on location.

An opportunity to study this question in Norfolk, Virginia, arose when the U. S. Navy created a 6.5 acre mitigation marsh on its property east of Willoughby Bay in 1983. The site, the Willoughby Disposal Area, was created in the 1950's (or earlier) by constructing a dike around 75-80 acres of the eastern part of Willoughby Bay and filling with dredge spoil from seaplane landing channels at the Naval Air Station. The area was roughly graded and drainage ditches provided which resulted in daily inundations of part of the area and subsequent colonization by numerous salt marsh plants and animals (Priest et al. 1982). In anticipation of the Navy's plan to place additional dredge spoil (from an aircraft carrier berth) in the area, the site was surveyed in December, 1981 (Priest et al. 1982).

The present study compares the flora and fauna of the newly-created marsh (Fig. 1) with an established natural marsh (Fig. 2) on the nearby Lafayette River. The project was undertaken jointly by Old Dominion University (ODU) and the Virginia Institute of Marine Science (VIMS). ODU compared fish, invertebrates and sediments, and VIMS, the flora.

MATERIALS AND METHODS

The location of the mitigation marsh, known as "Monkey Bottom," is shown in Fig. 3. Samples taken were compared with those from Larchmont Pond Marsh (Fig. 4). Figure 5 shows the location

Figure 1. Monkey Bottom marsh (low tide).

Figure 2. Larchmont Pond marsh (high tide).

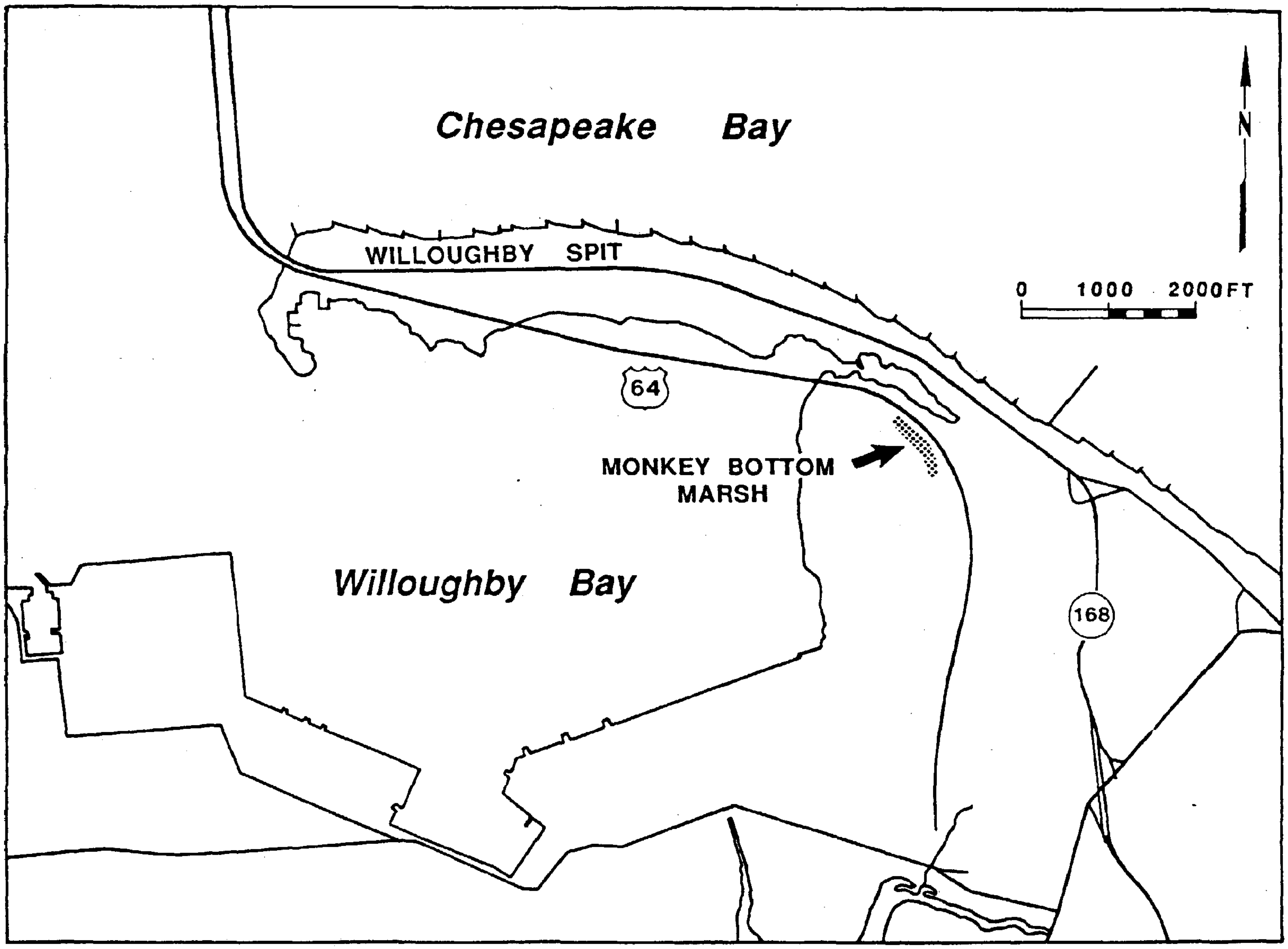


Figure 3. Location of the mitigation marsh, Monkey Bottom.

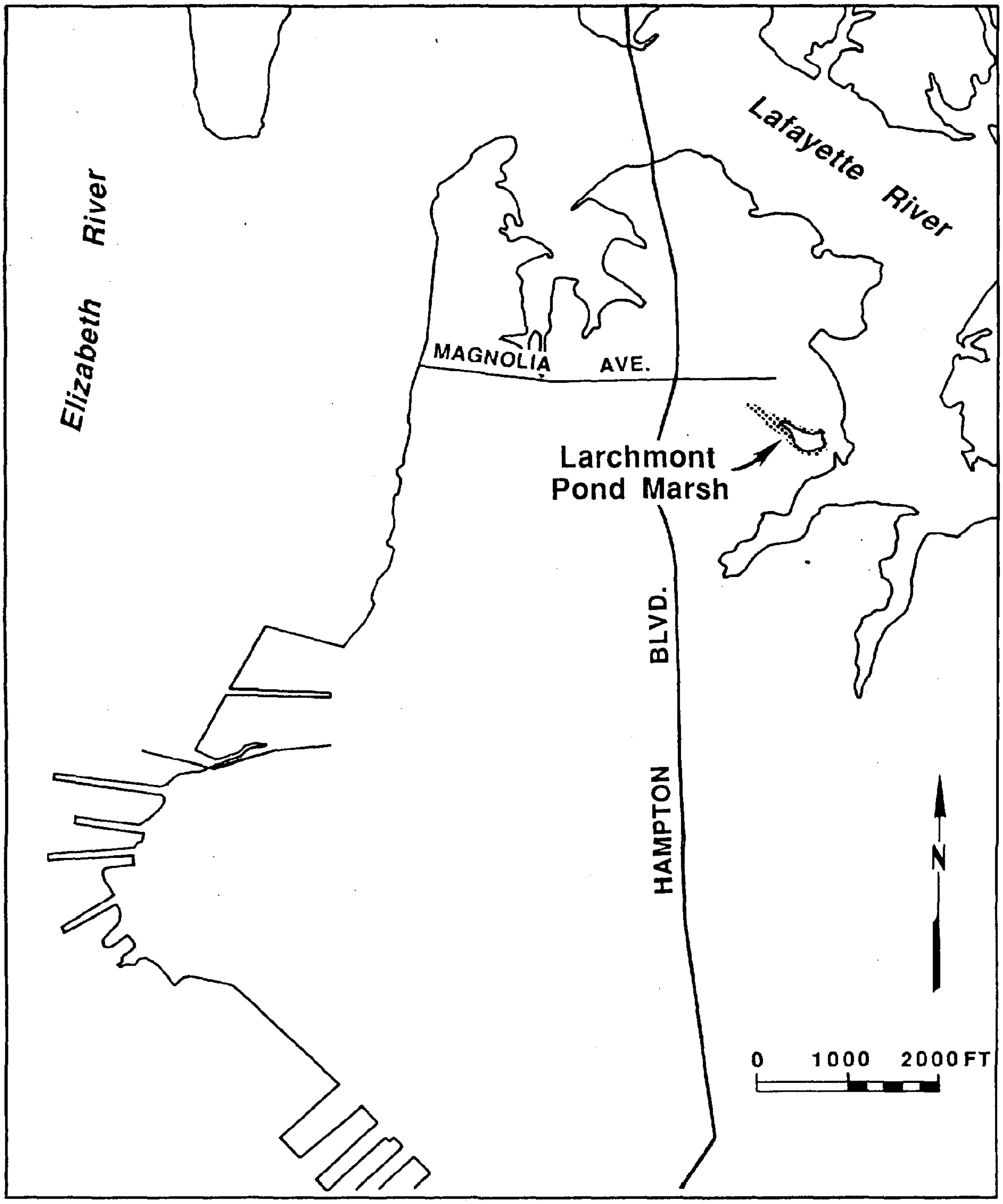


Figure 4. Location of the comparison marsh, Larchmont Pond.

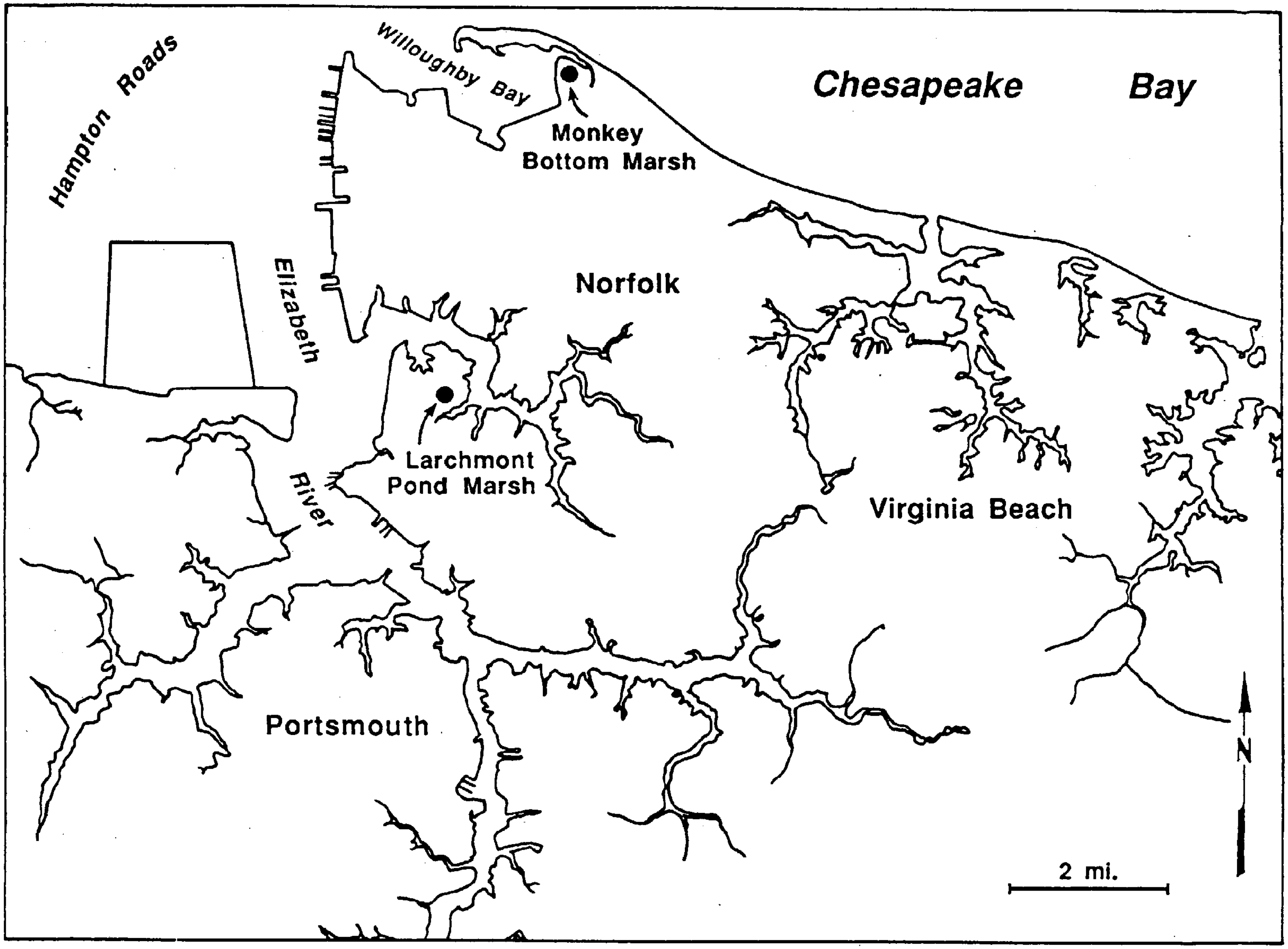


Figure 5. Locations of Monkey Bottom and Larchmont Pond marshes in relation to each other.

of each marsh in relation to the other.

Markers were placed along three tidal heights: approximately Spring High Tide, Spring Low Tide and midway between the two. The elevations above mean low water were subsequently measured by Norfolk city engineers and are approximately as follows:

	Monkey Bottom	Larchmont Pond
low	0	27 cm
medium	35 cm	35 cm
high	87 cm	85 cm

Sampling dates were August 26, and December 30, 1988, for Monkey Bottom, and September 17 and December 10, 1988 for Larchmont Pond marsh. The procedure was as follows.

Invertebrates - Cores, 10 cm (I.D.) and at least 20 cm into the sediment, were taken in replicate at three locations along each tidal height during summer and late fall (a total of 18 cores during each time period). Sediment was removed from the core in the field and seived through a 0.5 mm screen. All material which remained was placed in a cloth bag and preserved in a 15% Formalin/rose bengal solution. In the laboratory, organisms (which stain pink in the rose bengal) were removed and stored in alcohol. They were later identified to genus or family. Eight of the 72 cores were initially frozen instead of being fixed in Formalin. The frozen cores turned out to be of little subsequent value because organisms could not be accurately located in the samples without the benefit of stain. Table 1 shows the samples examined. However, six of the frozen samples were used for sediment carbon-nitrogen analysis (see below).

Sediments - Single box cores (one gallon rectangular cans: 7 cm x 10 cm x 20 cm deep) were taken at each tidal height of each

TABLE 1. Number of benthic samples analyzed for invertebrates.

	Summer		Winter	
Tidal Height	Monkey Bottom	Larchmont Pond	Monkey Bottom	Larchmont Pond
Low	5	5	6	6
Mean	4	4	6	6
High	5	5	6	6

marsh during the summer sampling period (a total of 12 cores). These were X-rayed and a grain-size analysis was performed on the sediments near the surface and at 20 cm depth. In addition, one of the 10 cm diameter cores from each tidal height from each marsh during the summer period was frozen and analyzed for carbon content on a CSN analyzer.

Temperature and Salinity - Temperature and salinity measurements were made during the summer sampling periods using a refractometer and ordinary thermometer.

Fishes and Mobile Invertebrates - A stop net was placed across the culvert of each marsh in summer to fish the outgoing tide (Figs. 6, 7). Fish and invertebrates caught were identified, counted and released (Fig. 8). In addition, baited minnow traps were set nine times at Monkey Bottom and eight times at Larchmont Pond during the summer sampling period.

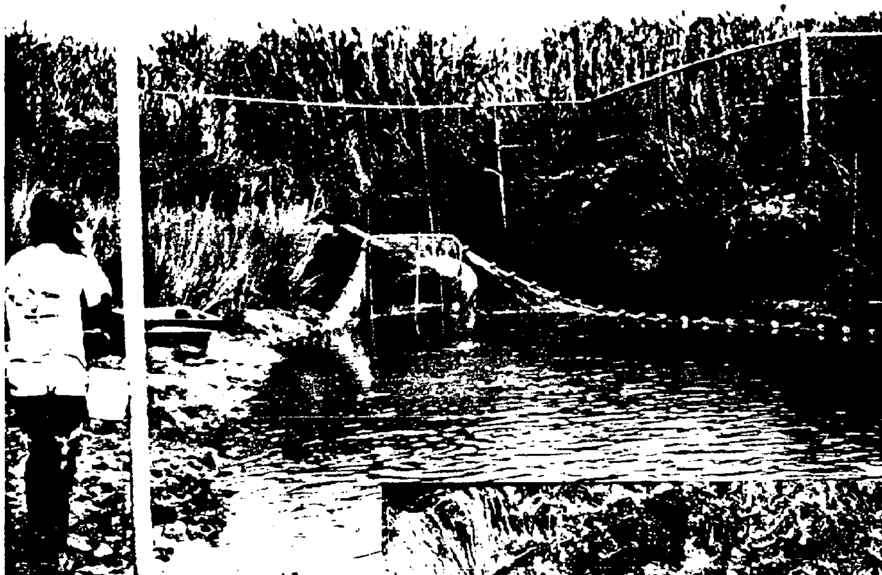
Birds - Dr. Carvel Blair made a comparison of birds present between Monkey Bottom and Big Marsh Island (a marsh near Larchmont Pond marsh). His study is provided in Appendix II.

RESULTS

SEDIMENTS

X-ray radiographs of box cores are shown in Fig. 9. The results indicate that since its construction in 1983, the Monkey Bottom marsh has accumulated 2-11 cm (mean = 4) of marsh deposits, overlying compacted older material. The high tide and mid-tide box cores penetrated several centimeters of new sediment, then passed into the older deposit. The low-tide box core, 1A, was taken entirely within a thick layer of new sediment that has accumulated with the central channel. The new sediment has a low water content (33-40%) and contains quantities of sand (8-48%) (Fig. 10) The new marsh sediment rests on compacted older deposits, characterized by a low water content (30-35%) and one grain size (>5% sand) (Fig. 10,IA-C).

At Larchmont Pond marsh, the low tide sample consists of sediment with consistently high sand content (34-52%) and consistently high water content (53-64%). Mid and high-tide samples also have high sand content, but less water (20-30%) (Fig. 10, IIA-C).



⇐ Figure 6.
Stop net across culvert at Monkey Bottom marsh.

Figure 7. ⇒
Stop net across culvert at Larchmont Pond marsh.

⇐ Figure 8.
Removing fishes and mobile invertebrates from the stop net at Monkey Bottom marsh.

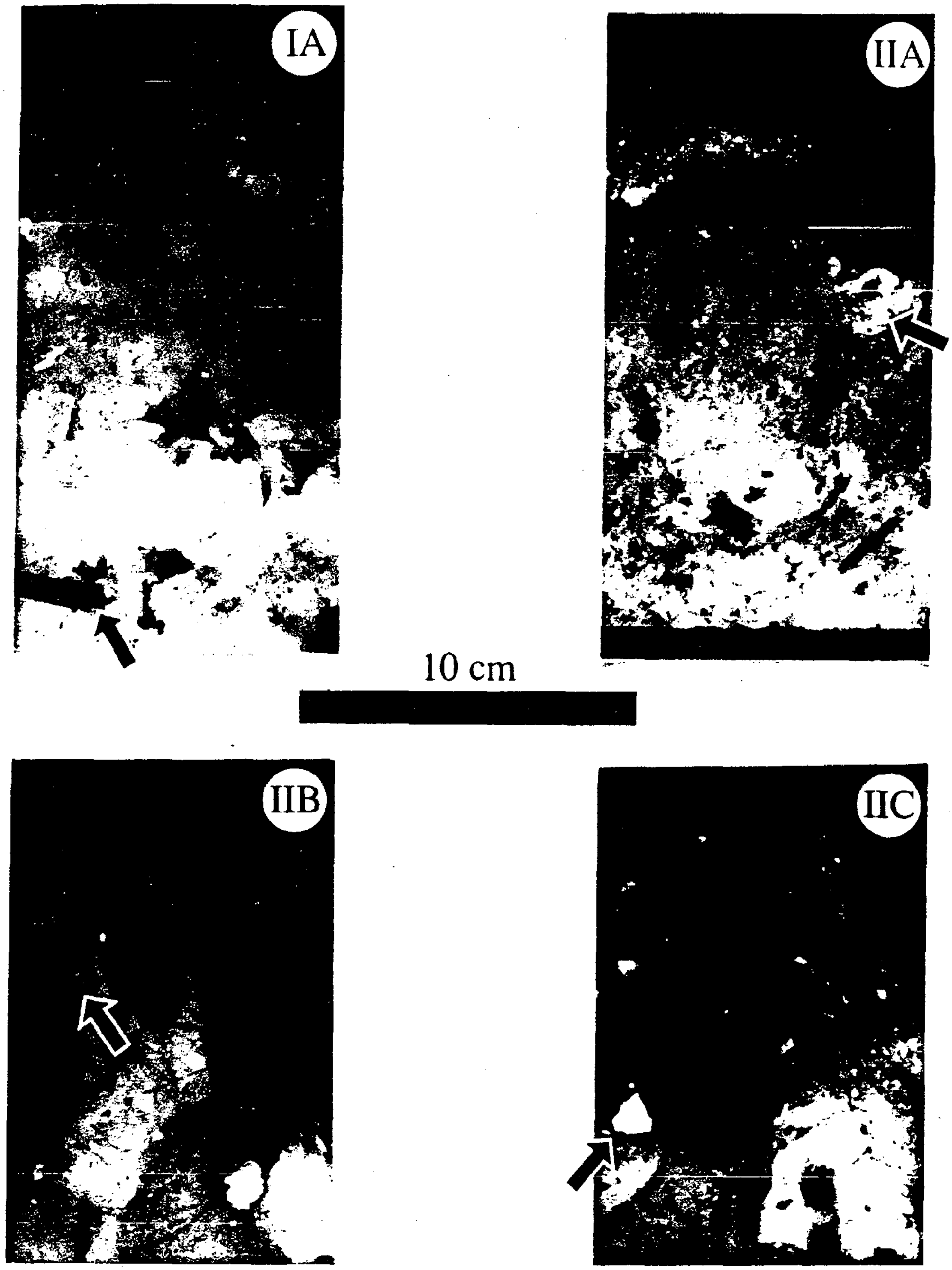


Figure 9. X-ray radiographs showing depositional features of samples of Monkey Bottom and Larchmont Pond. I and II refer to Monkey Bottom and Larchmont Pond, respectively. A = low tide, B= mid tide, C = high tide. In IA, arrow points to polecypod shell (Ensis, sp.). In IIA, arrow points to bone fragment. In IIC, arrow points to cement chip.

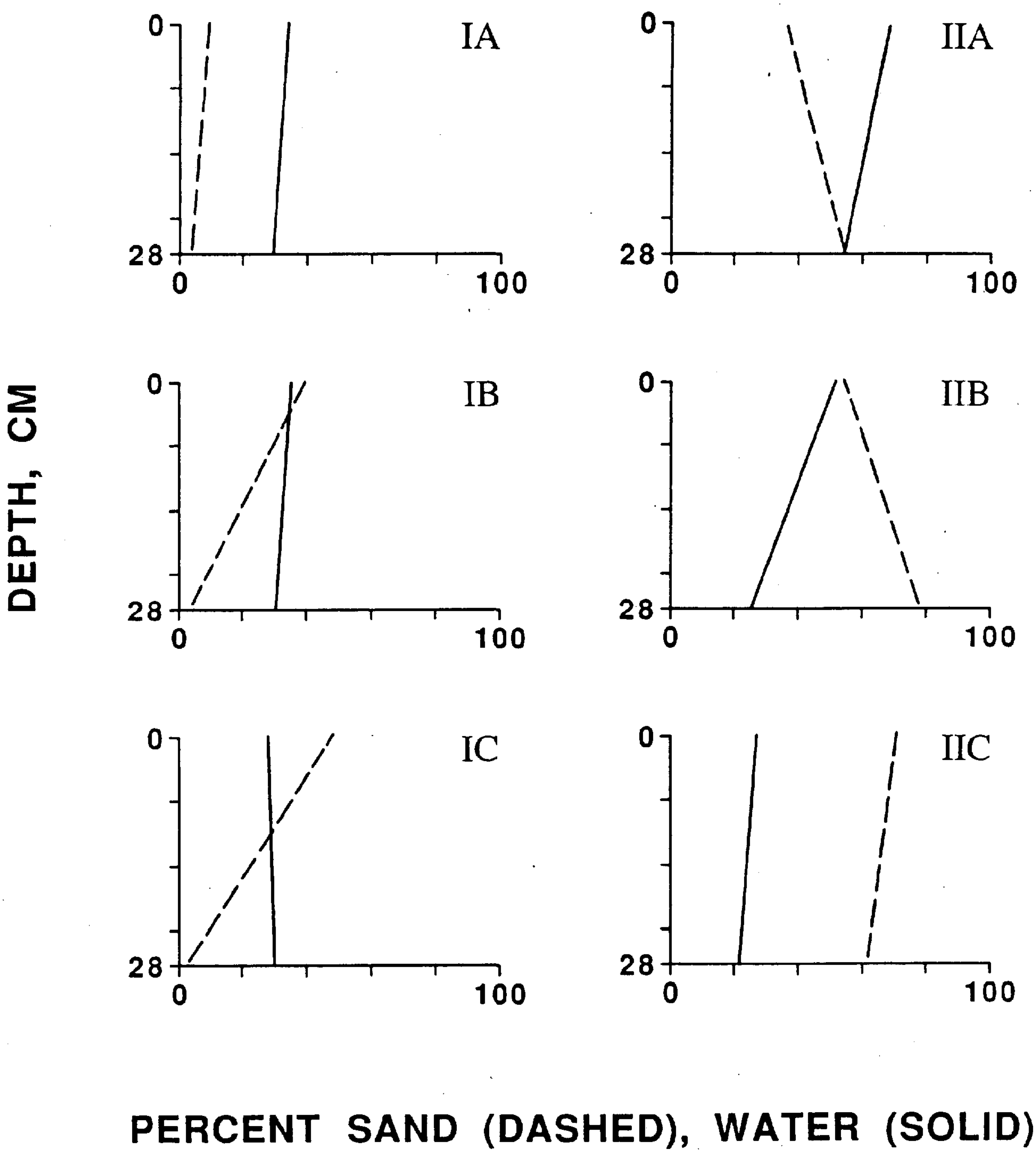


Figure 10. Percentage of water and sand in sediments at Monkey Bottom and Larchmont Pond. IA, IB, IC = Monkey Bottom at low, middle and high tide locations, respectively. IIA, IIB, IIC = Larchmont Pond at low, middle and high tide locations, respectively.

The organic contents of the sediments are indicated by the carbon and nitrogen values shown in Table 2.

The Monkey Bottom samples have relatively low carbon values (1.03 - 2.26%). The low tide sample, taken in the tidal channel,

TABLE 2. Percent Total Organic Carbon in the Sediments.

MONKEY BOTTOM		**LARCHMONT POND**	
IL Top	2.26	IIL Top	11.62
IL Bottom	1.57	IIL Bottom	9.25
IM Top	1.03	IIM Top	4.47
IM Bottom	1.50	IIM Bottom	1.24
IH Top	1.55	IIH Top	1.97
IH Bottom	2.03	IIH Bottom	2.04

has a relatively organic-rich layer at the top (2.26%). In the other two cases, the profile is anomalous. The older, compact sediment at depth is richer in organic material than is the new sediment at the top of the profile (2.26% versus 1.76%).

The Larchmont pond samples are significantly richer in organic carbon (1.24-11.62%) than are the Monkey Bottom samples. The low tide sample (11.62%) approaches a gyttja (carbon rich lake sediment). At Larchmont pond only the sandy, near-embankment high tide sample has a reversed profile (top 1.97% carbon, bottom 2.04% carbon).

TEMPERATURE AND SALINITY

At monkey bottom summer readings were 27°C and 23‰ . They were 26°C and 21‰ at Larchmont Pond a few weeks later.

INVERTEBRATES

A list of organisms found in the benthic cores is given in Table 3 by marsh, tidal height and sample date (a complete listing

Table 3. Total number of organisms found in the samples during the two sampling periods. Average number of organisms per sample in parenthesis.

Station*	Date	Clams: Hard Mercenaria	Clams: Soft Mya	Clams: Razor Ensis	Mussel Modiolus	Crab Uca	Annelids: N	Annelids: C	Annelids: S	Nematodes	Amphipod	Isopod	Other**	Total
MB-L	8-26	5 (1.0)	19 (3.8)	0	0	0	49 (9.8)	57 (11.4)	2 (0.4)	0	0	0	0	132 (26.4)
MB-M	8-25	8 (2.0)	19 (4.8)	5 (1.3)	0	0	57 (14.3)	9 (2.3)	0	0	0	0	0	98 (24.5)
MB-H	8-26	0	0	0	0	0	0	0	0	0	2 (0.4)	0	1 (0.2)	3 (0.6)
LP-L	9-17	0	0	0	0	0	0	0	0	18 (3.6)	0	0	0	18 (3.6)
LP-M	9-17	0	0	0	0	0	10 (2.5)	1 (0.3)	0	126 (31.5)	0	1 (0.3)	0	138 (34.5)
LP-H	9-15	1 (0.2)	0	0	0	3 (0.6)	2 (0.4)	0	0	12 (2.4)	0	5 (1.0)	7 (1.4)	30 (6.0)
MB-L	12-30	3 (0.5)	15 (2.5)	1 (0.2)	0	0	31 (5.2)	19 (3.2)	0	0	0	0	0	69 (11.5)
MB-M	12-30	2 (0.3)	7 (1.2)	0	0	0	68 (11.3)	88 (14.7)	0	14 (2.3)	1 (0.2)	0	0	180 (30.0)
MB-H	12-23	0	0	0	0	0	0	0	0	0	1 (0.2)	0	0	1 (0.2)
LP-L	12-10	0	0	0	0	0	7 (1.2)	4 (0.7)	0	809 (134.8)	0	1 (0.2)	0	821 (136.8)
LP-M	12-10	0	0	0	3 (0.5)	2 (0.3)	0	0	0	252 (42.0)	0	5 (0.8)	1 (0.2)	263 (43.8)
LP-H	12-10	1 (0.2)	0	0	0	2 (0.3)	0	0	0	2 (0.3)	0	1 (0.2)	0	6 (1.0)

*-MB = Monkey Bottom marsh, LP = Larchmont Pond marsh. L - low tide, M - mean tide, and H - high tide.

**- MB-H (8-26) other - copepod (1)

LP-H (9-15) other - copepod (2), <u>Sagitta</u> (1), <u>Littorina</u> (1), insects and arachnids (3)

LP-M (12-10) other - <u>Crangon</u> (1)

Annelids:

N - Nereidae

C - Capitillidae

S - Spionidae

Amphipod - Gammaridae

Isopod - Anthuridea

of all organisms found by sample is given in Appendix I). At Monkey Bottom, the low and medium tidal samples were characterized by three species of clams (hard, soft and razor) and relative abundance of two families of polychaete worms. High tide samples had very few organism. Fiddler crabs and the snail, _Littorina_ were notably scarce. There was little difference between summer and winter (Fig. 11).

At Larchmont Pond, samples were characterized by small nematode worms, particularly in the late fall samples. Fiddler crabs were extremely abundant, but too mobile to be caught in any numbers in the core samples. Few _Littorina_ were observed in the marsh. The horse mussel, _Modiolus_, was observed along the edge of the marsh and taken in one of the samples. Only two clams, both _Mercenaria_ were taken in the Larchmont Pond samples, vs 84 in the Monkey Bottom samples. With nematodes excluded, there were few organisms in the samples in either period (Fig. 12).

If nematodes are excluded Monkey Bottom had far more organisms than Larchmont Pond in the sediment samples of both seasons (Figs. 13 and 14).

Pie diagrams of Fig. 15 illustrate the dominance of polychaetes in Monkey Bottom samples (75.2 and 82.3% of all organisms) and nematodes in those of Larchmont Pond (84.8 and 97.7% of all organisms).

Benthic samples taken by Priest _et al_. (1982) in December 1981 were from the tidal ditches of the Willoughby Disposal Area (before the area was filled in and the mitigation marsh created). The location of their samples is most similar to our low and

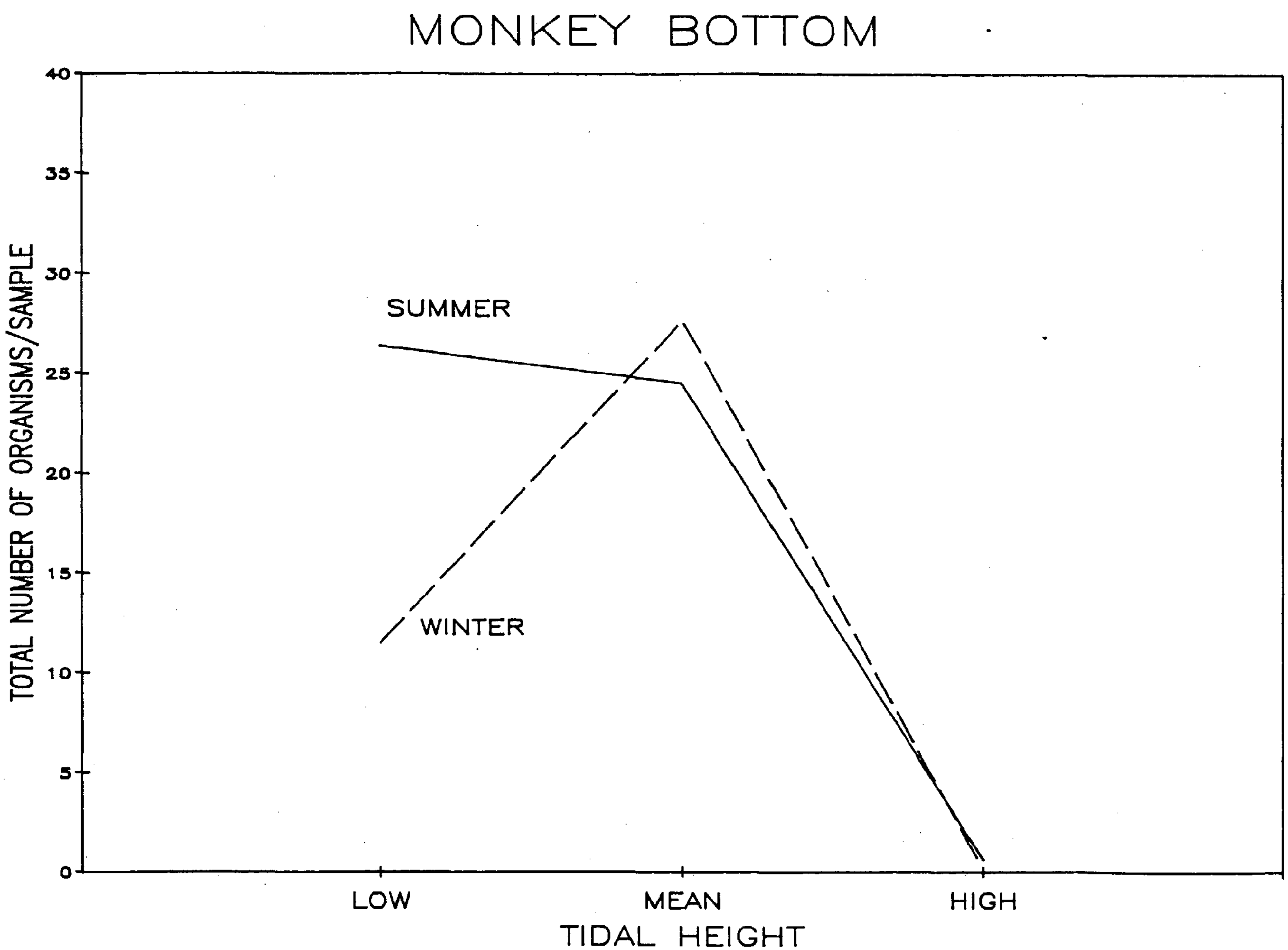


Figure 11. Number of organisms found per sample at Monkey Bottom by tidal height (excluding nematodes).

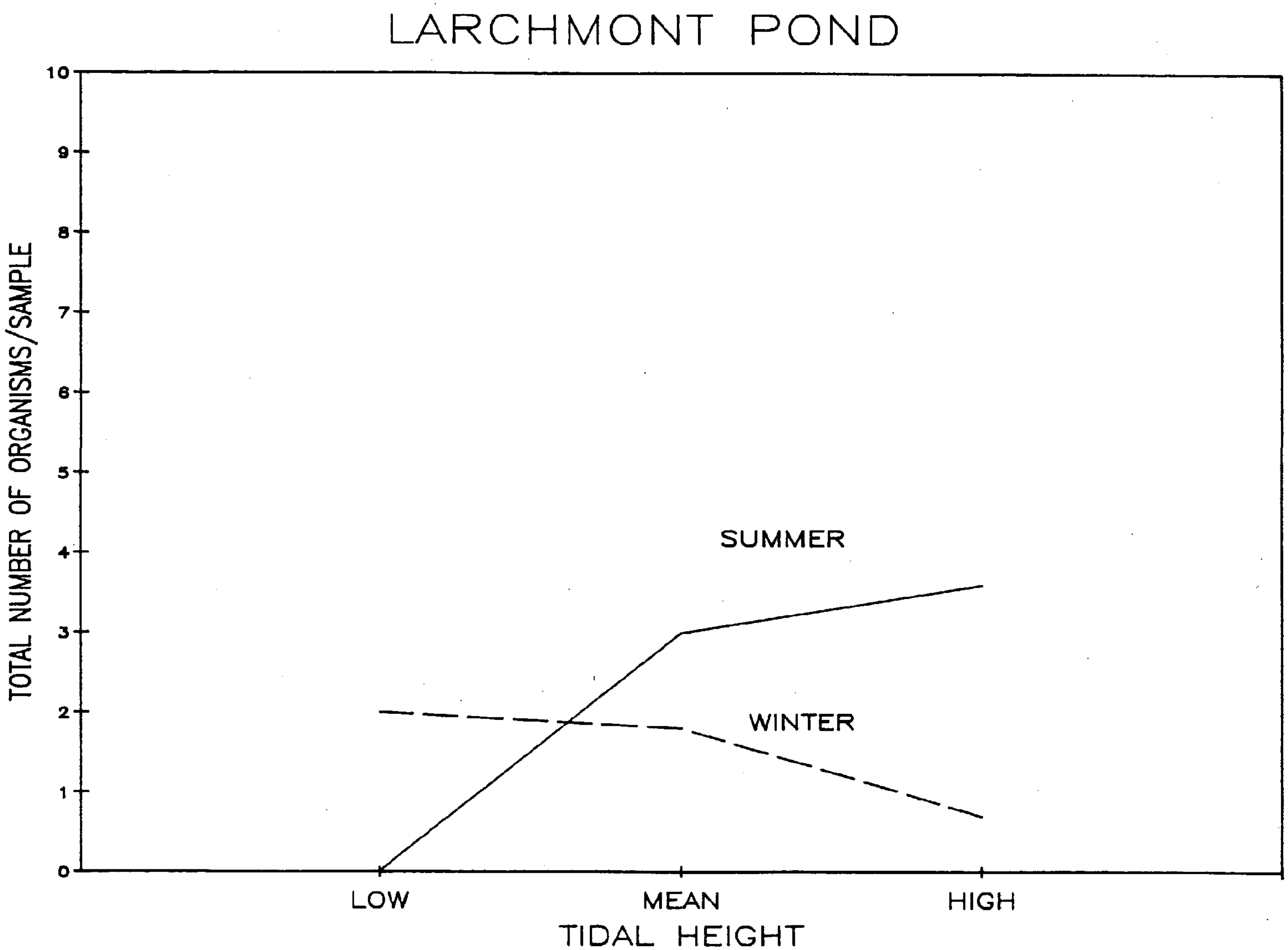


Figure 12. Total number of organisms found per sample by tidal height at Larchmont Pond, summer vs winter (excluding nematodes).

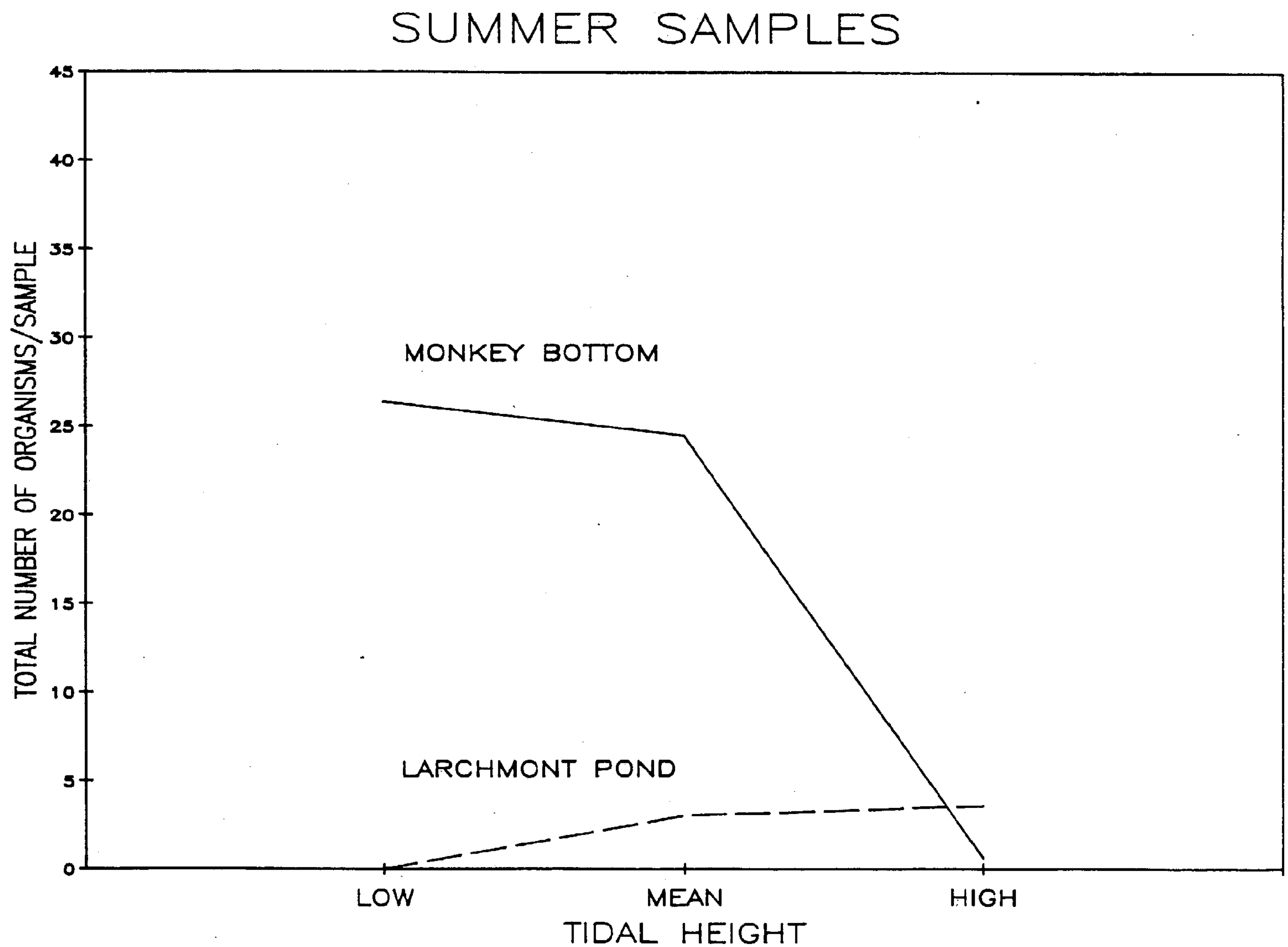


Figure 13. Number of organisms found per sample by tidal height in summer, Monkey Bottom vs Larchmont Pond (nematodes excluded).

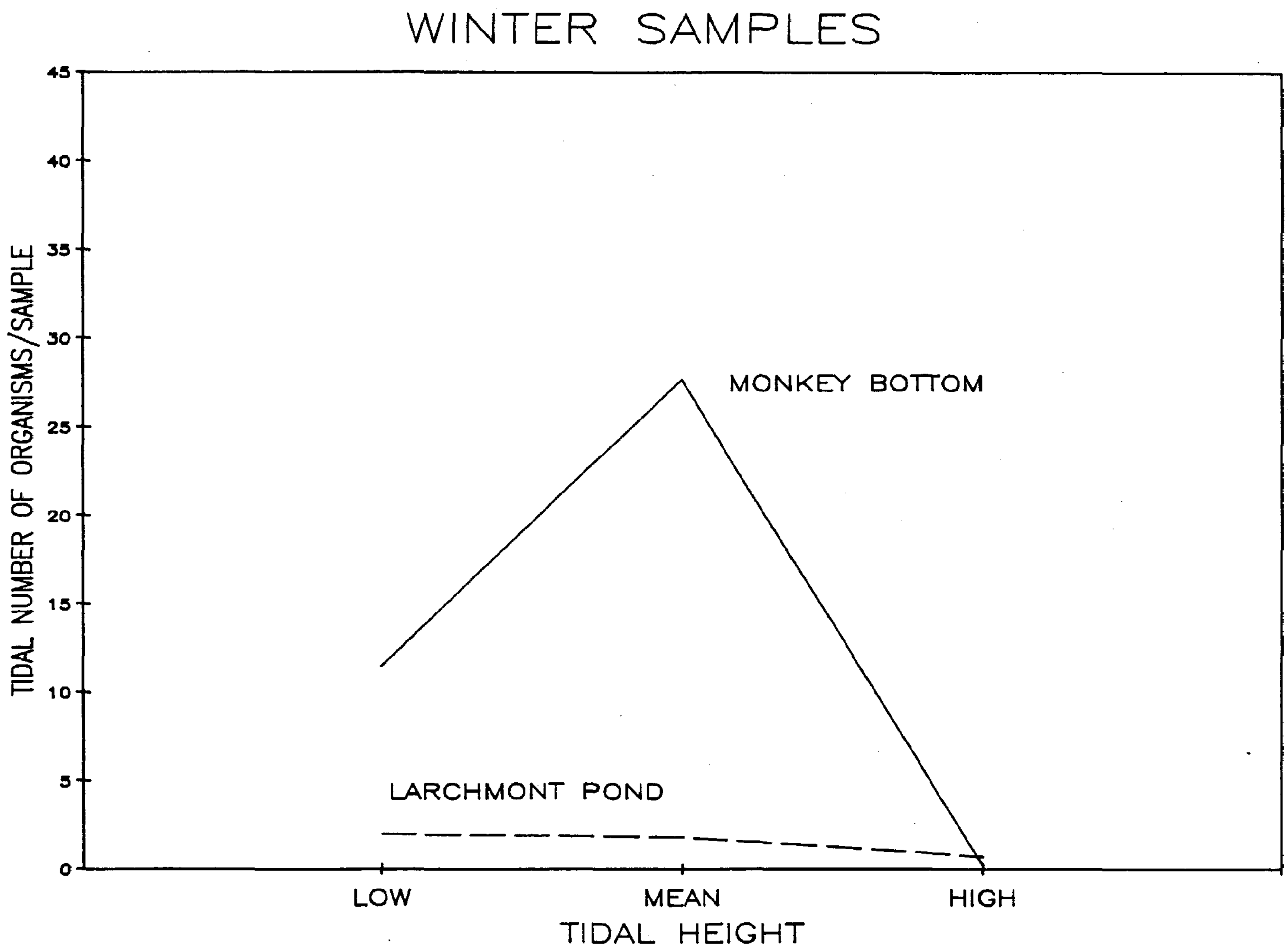


Figure 14. Number of organisms found per sample by tidal height in winter, Monkey Bottom vs Larchmont Pond (excluding nematodes).

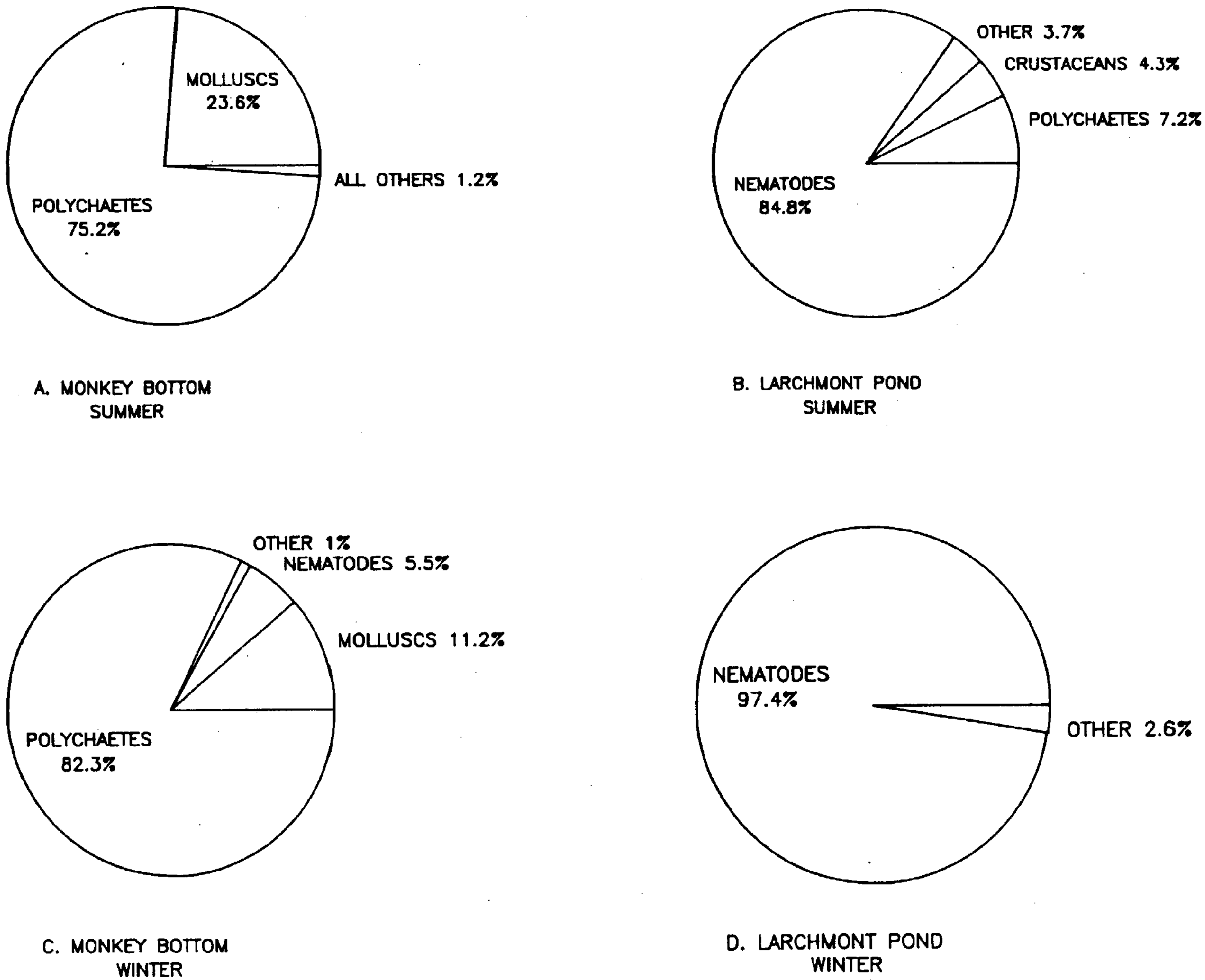


Figure 15. Relative proportion of infaunal invertebrates found in the sediments.

medium height samples. Priest et al. (1982) found an average of 16.3 annelids, 0.53 molluscs and 1.06 crustaceans in an area equivalent to our 3.75" core samples. This is similar to our findings in annelids (17.2/sample) in December at Monkey Bottom. We found more molluscs (2.35/sample) but fewer crustaceans (0.1) than the previous workers. When the differences in sample location is considered, the number of infaunal organisms in the new marsh in winter appears more or less the same as the 1981 marsh.

FISHES and MOBILE INVERTEBRATES

Stop net results are shown in Table 4 and Fig. 16. The Monkey Bottom fish were characterized by juveniles of white and striped mullett, menhaden and spot. Mummichogs and silversides were also taken. In addition to fish, there were a large number of blue crabs in the net. At Larchmont Pond, the fish caught were primarily young menhaden, and silversides and mummichogs. Large mullett were often observed jumping in the pond and over the net, but none were caught.

The minnow trap catches are listed in Table 5. These were employed primarily to sample the killifish populations, as these fish do not leave the pond during tidal ebb as readily as other species. The catch of mummichogs was similar in absolute number, but there were three-and a half times as many killifish caught per unit time in Larchmont Pond as in Monkey Bottom (2.5 fish/trap minute vs. 0.71 fish/trap-min). Caution should be taken when interpreting these results because, for logistical reasons, the traps at Larchmont Pond were not set for as long a time as those at Monkey Bottom.

Table 4. Number of organisms caught in the stop net at the two sites during the summer period.

Fish	Monkey Bottom	Larchmont Pond
Anchoa sp. (anchovy)	0	4
Anguilla rostrata (eel)	3	1
Brevoortia tyrannus (menhaden)	107	103
Dorosoma cepedianum (gizzard shad)	0	1
Fundulus heteroclitus (mummichog)	96	70
Fundulus majalis (striped killifish)	1	0
Leiostomus xanthurus (spot)	39	0
Menidia menidia (silverside)	20	34
Micropogonias undulatus (croaker)	1	0
Mugil cephalus (striped mullet)	160	0
Mugil curema (white mullet)	539	0
Mugil spp. (mullet)	0	*
Trinectes macalatus (hogchoker)	5	0
Invertebrates		
Callinectes sapidus (blue crab)	259	15
Hippolyte sp. (grass shrimp)	48	1
Penaeus sp. (penaeid shrimp	1	0

* mullet were seen, however, they avoided the net.

Table 5. Number of fish caught in minnow traps at the two sites during the summer period. Number of fish per minute in parenthesis.

Fish	Monkey Bottom	Larchmont Pond
Total time fished	745 min	240 min
Anguilla rostrata (eel)	0	1
Cyprinodon variegatus (sheepshead minnow)	0	1
Fundulus heteroclitus (mummichog)	531 (0.712)	611 (2.546)
Fundulus majalis (striped killifish)	2	1
Gobiidae (Goby)	0	1
Leiostomus xanthurus (spot)	1	0
Menidia menidia (silverside)	0	3
Morone americana (white perch)	1	0
Mugil curema (white mullet)	18	0

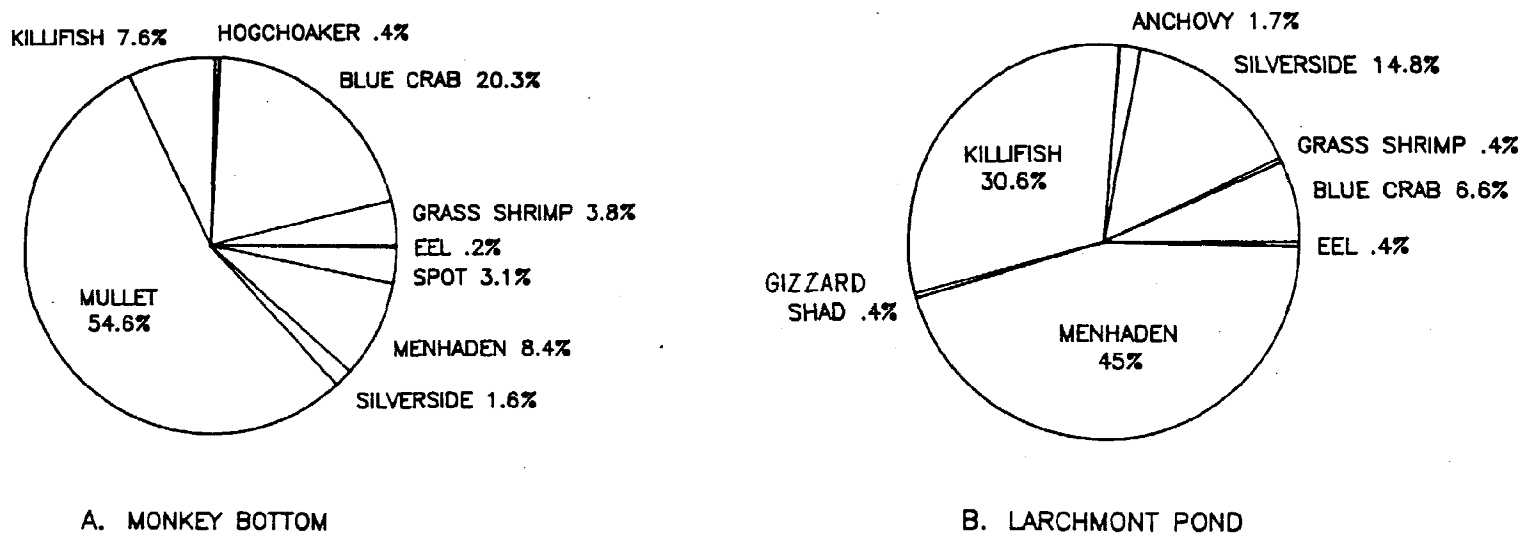


Figure 16. Relative proportion of mobile fish and invertebrates caught in stop nets.

DISCUSSION

NATURE OF MARSH DEPOSITS

Coastal salt marshes are underlain by distinctive marsh deposits. These are not soils in the strict sense of a weathering residuum, but are sediments which have been eroded elsewhere, transported and redeposited. There is a strongly positive feedback between the growth of marsh flora and the deposition of underlying sediment. Marsh plants only grow in the protected parts of coastal estuaries and lagoons where wave activity is reduced, and only fine sediment can be delivered by the sediment dispersal system, for which system the marsh constitutes the terminal sink. In return, the plants of the marsh surface form a bafflework which modifies the flow of water at high tide, accelerates the deposit of fine sediment, and controls the size range of deposited particles.

Freshly deposited marsh sediment contains up to 96 percent water by weight. As the sediment accumulates, it compacts and expels its interstitial water, so that at a depth of 100 cm, the water content may have decreased to 45 percent. Marsh sediment retains its water because it is highly porous, but the pores are so fine that fluids do not easily pass through them, and the permeability is low.

COMPOSITION OF MARSH DEPOSITS

The character of marsh sediment varies by region in response to climate, the available sediment and the composition of the marsh community. High latitude marsh deposits have been reworked from glacial tills. They typically contain less than 10 percent by dry weight of organic matter, and consist primarily of silt-sized quartz particles (4 to 64 microns). Marsh deposits in the Mississippi Delta often consist almost entirely of peaty organic matter. Marsh deposits of the central and southern Atlantic coast of the U. S., including those of Chesapeake Bay, and intermediate in character, and typically consist of less than 15 percent silt, 30 percent clay sized mineral matter (less than 4 microns) and 20 percent or less of silt and clay sized organic matter. See summary in Frey and Basan, 1985.

Marsh deposits accumulate both in situ and far-travelled organic matter. Anaerobic decay results in the remineralization of essential nutrients, which are slowly released through the sponge-like marsh substrate. Both the organic matter and the clay minerals which are brought to the marsh are efficient scavengers of trace metals and complex organic pollutants. Marshes therefore fulfill a cleansing role with respect to coastal systems, analogous to the function of the liver in the human circulatory system.

SUBSTRATE AT MONKEY BOTTOM AND LARCHMONT POND MARSH

At Monkey Bottom, the two characteristics of low water and high sand content of the new surficial sediment are probably related. The new sediment has an anomalously low water content despite being freshly deposited because it is so sandy and, therefore, cannot hold as much water. The sandy nature of the sediment stems from the steep slopes of the adjacent dredge spoil and the road bed of I-64; rain washes sand into the marsh.

The compacted older sediment may be older marsh, buried when the Navy dredged Willoughby Bay and dumped the spoil on it, then reexposed when the area was bulldozed down to mean low water to create the mitigation marsh. It is also possible that it is older fine-grained sediment, initially deposited in Willoughby Bay, dredged by the Navy in 1942, and dumped into its present position and, subsequently, compacted under the weight of additional fill. More cores are needed to resolve this issue. The single razor shell clam, Ensis sp. in the X-ray radiograph (Fig. 4 IA) is not diagnostic of either environment.

The older material is almost sand-free. Its low water content is due to burial and compaction. It is "overconsolidated" in the sense that its water content is anomalously low. As a result, shear strength of the sediment is high. Consequently, the cores did not deform plastically, but were fractured during the coring process by the lightweight corers that we used (Fig. 4 IA). The present channels within the marsh, up to 75 cm deep, are incised into the older deposits.

At Larchmont Pond marsh, the high water content of the low tide sample suggests rapid sedimentation in the pond after the construction of the Jamestown Crescent causeway. Because sedimentation was rapid, the sediment was less able to expel pore water before burial, hence, the sediment is "underconsolidated." The mid and high tide samples contain less water because they drain more fully during the tidal cycle. All samples are sand rich due to wash from the causeway (note also bone fragment and cement chips in the X-ray radiograph) (Figs. 9, IIA and IIB, respectively).

INVERTEBRATE COMMUNITIES

The two marshes receive tidal flow in a similar manner -- through a culvert. The Monkey Bottom marsh drains to Willoughby Bay which lies adjacent to Chesapeake Bay. Larchmont Pond marsh, approximately 9.5 km upstream, drains into the Lafayette River which connects to the Elizabeth River before entering the Chesapeake Bay. Monkey Bottom marsh is larger than Larchmont Pond marsh (6.5 v. 2.0 acres) and drains more completely than the Larchmont Pond marsh at low tide.

The infaunal invertebrates of the two marshes appear to represent different communities, presumably due to differences in location and sediment characteristics. The mobile fauna were quite similar, with the exception of fiddler crab populations. The absence of a large number of fiddler crabs at Monkey Bottom may possibly be explained by lower level of sediment organics which also affects sediment grain size and water characteristics. These can be expected to improve as the marsh ages.

Fishes and mobile invertebrates at Monkey Bottom were abundant during the summer sampling and compared favorably with those at Larchmont Pond marsh. The number of larger organisms (nematodes excluded) in the sediment was higher than at the Larchmont Pond marsh and, for December, was similar to the numbers in pre-marsh samples of the Willoughby Disposal Area (Priest et al., 1982).

CONCLUSION

At Monkey Bottom, a thin veneer of modern marsh sediment is forming over older "overconsolidated" sediment. Because of this, the marsh may be less efficient than a natural marsh in remineralizing and releasing nutrients, or in sequestering contaminants. The dense substrate is probably also less congenial to burrowing invertebrates and *Spartina* rhizomes. On the other hand, it is probably a stroke of luck that this substrate is fine-grained marine sediment (either old marsh or open bay deposit. Willoughby Spit and the adjacent mainland are composed of well-sorted, permeable sand. Mitigation marshes built directly on such substrate have performed poorly (Zedler *et al.*, in press).

Based on our examination of the sediments and faunal composition the Monkey Bottom marsh appears to be healthy and functioning in several beneficial ways.

1. The marsh is being utilized as a nursery area by two species of mullet, menhaden, spot, silversides and killifish, as well as by blue crabs and grass shrimp;

2. The marsh also serves as a forage area for the above species and many birds;

3. The marsh is accumulating organic materials in the sediments some of which will eventually wash into nearby waterways enhancing their food chains.

ACKNOWLEDGEMENTS

This study was funded by the City of Norfolk with funds provided by the Council of the Environment. We thank Captain Jack Buffington, Navy Public Works Center, for allowing us access to Monkey Bottom marsh. Walt Priest of the Virginia Institute of Marine Science lent us the stop net and aided us in the field. Jeff Gardiner of Old Dominion University and Steve Sokolowski of the Applied Marine Research Laboratory (ODU) performed the X-ray and organic carbon analyses, respectively. Mark Bushing served as research associate, and worked on all phases of the project including field work, identification of the infaunal invertebrates, and data analysis.

REFERENCES CITED

Frey, R. W. and Basan, P. B., 1985. "Coastal Salt Marshes," pp. 225-301 in Davis, R. A., Coastal Sedimentary Environments. Springer Verlag, New York.

Priest, W. I. III, C. R. Terman and W. Ihle, 1982. "A Natural Resources Survey and Habitat Evaluation of the Willoughby Disposal Area," U. S. Naval Base, Norfolk, Virginia. Final Report prepared for Department of the Navy, Atlantic Division, Naval Facilities Engineering Command, Norfolk, VA 29p.

Swift, D. J. P., W. L. Stubblefield, T. L. Clarke, R. A. Young, G. L. Freland, G. Havey and B. Hillard, 1985. Sediment budget near the New York Dumpsites: Implications for pollutant dispersal. In I. Duedall, Wastes in the Ocean, V. 6, Nearshore waste disposal. New York, John Wiley and Sons, pp. 568-599.

Zedler, J. B., R. Langis, J. Cantilli, M. Zalejko and S. Rutherford, in press. "Assessing the successful functioning of successful salt marshes." Soc. Ecol. Restoration Management Annual Meeting, January 16-20, 1989, Oakland, CA.

APPENDICES

APPENDIX I

Total number of invertebrates found in the benthic samples.

Station (Date)	Mercenaria	Mya	Ensis	Modiolus	Uca	Nereidae	Capitillidae	Spionidae	Nematodes	Amphipod	Isopod	Other*
MB-L (8-26-88)	Ø	2	Ø	Ø	Ø	7	1Ø	1	Ø	Ø	Ø	Ø
MB-L (8-25-88)	Ø	4	Ø	Ø	Ø	6	2	Ø	Ø	Ø	Ø	Ø
MB-L (8-25-88)	Ø	5	Ø	Ø	Ø	14	14	1	Ø	Ø	Ø	Ø
MB-L (8-26-88)	4	7	Ø	Ø	Ø	11	23	Ø	Ø	Ø	Ø	Ø
MB-L (8-25-88)	1	1	Ø	Ø	Ø	11	8	Ø	Ø	Ø	Ø	Ø
MB-M (8-25-88)	3	6	Ø	Ø	Ø	24	9	Ø	Ø	Ø	Ø	Ø
MB-M (8-25-88)	Ø	5	3	Ø	Ø	5	Ø	Ø	Ø	Ø	Ø	Ø
MB-M (8-25-88)	3	4	1	Ø	Ø	16	Ø	Ø	Ø	Ø	Ø	Ø
MB-M (8-25-88)	2	4	1	Ø	Ø	12	Ø	Ø	Ø	Ø	Ø	Ø
MB-H (8-26-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	1
MB-H (8-26-88)	EMPTY											
MB-H (8-26-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	Ø
MB-H (8-26-88)	EMPTY											
MB-H (8-26-88)	EMPTY											
LP-L (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	5	Ø	Ø	Ø
LP-L (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	5	Ø	Ø	Ø
LP-L (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	4	Ø	Ø	Ø
LP-L (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	3	Ø	Ø	Ø
LP-L (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	Ø	Ø	Ø
LP-M (9-15-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	25	Ø	Ø	Ø
LP-M (9-17-88)	Ø	Ø	Ø	Ø	Ø	1	1	Ø	73	Ø	1	Ø
LP-M (9-17-88)	Ø	Ø	Ø	Ø	Ø	6	Ø	Ø	1	Ø	Ø	Ø
LP-M (9-17-88)	Ø	Ø	Ø	Ø	Ø	3	Ø	Ø	27	Ø	Ø	Ø
LP-H (9-17-88)	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	5	Ø	Ø	Ø
LP-H (9-15-88)	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1	4
LP-H (9-15-88)	Ø	Ø	Ø	Ø	Ø	1	Ø	Ø	2	Ø	4	3
LP-H (9-15-88)	Ø	Ø	Ø	Ø	2	Ø	Ø	Ø	1	Ø	Ø	Ø
LP-H (9-15-88)	Ø	Ø	Ø	Ø	1	1	Ø	Ø	4	Ø	Ø	Ø

*Other:
MB-H (8-26-88) - copepod (1)
LP-H (9-15-88) - copepod (2), Sagitta (1), Littorina (1), insects and arachnids (3)

Appendix 1. Continued.

Station (Date)	Mercenaria	Mya	Ensis	Modiolus	Uca	Nereidae	Capitillidae	Spionidae	Nematodes	Amphipod	Isopod	Other*
MB-L (12-30-88)	0	2	0	0	0	2	2	0	0	0	0	0
MB-L (12-30-88)	1	2	0	0	0	7	7	0	0	0	0	0
MB-L (12-30-88)	0	0	0	0	0	5	1	0	0	0	0	0
MB-L (12-30-88)	0	2	0	0	0	4	8	0	0	0	0	0
MB-L (12-30-88)	2	6	0	0	0	8	0	0	0	0	0	0
MB-L (12-30-88)	0	3	1	0	0	5	1	0	0	0	0	0
MB-M (12-30-88)	2	1	0	0	0	25	31	0	5	1	0	0
MB-M (12-30-88)	0	0	0	0	0	12	23	0	6	0	0	0
MB-M (12-30-88)	0	2	0	0	0	3	7	0	0	0	0	0
MB-M (12-30-88)	0	4	0	0	0	6	0	0	0	0	0	0
MB-M (12-30-88)	0	0	0	0	0	13	27	0	3	0	0	0
MB-M (12-30-88)	0	0	0	0	0	9	0	0	0	0	0	0
MB-H (12-23-88)	0	0	0	0	0	0	0	0	0	1	0	0
MB-H (12-23-88)	A PIECE OF CRAB SHELL											
MB-H (12-23-88)	EMPTY											
MB-H (12-23-88)	EMPTY											
MB-H (12-23-88)	EMPTY											
MB-H (12-23-88)	EMPTY											
LP-L (12-10-88)	0	0	0	0	0	3	0	0	111	0	0	0
LP-L (12-10-88)	0	0	0	0	0	0	0	0	82	0	0	0
LP-L (12-10-88)	0	0	0	0	0	4	4	0	316	0	0	0
LP-L (12-10-88)	0	0	0	0	0	0	0	0	100	0	1	0
LP-L (12-10-88)	0	0	0	0	0	0	0	0	100	0	0	0
LP-L (12-10-88)	0	0	0	0	0	0	0	0	100	0	0	0
LP-M (12-10-88)	0	0	0	2	2	0	0	0	2	0	2	0
LP-M (12-10-88)	0	0	0	1	0	0	0	0	30	0	3	1
LP-M (12-10-88)	0	0	0	0	0	0	0	0	100	0	0	0
LP-M (12-10-88)	0	0	0	0	0	0	0	0	10	0	0	0
LP-M (12-10-88)	0	0	0	0	0	0	0	0	10	0	0	0
LP-M (12-10-88)	0	0	0	0	0	0	0	0	100	0	0	0
LP-H (12-10-88)	0	0	0	0	0	0	0	0	2	0	1	0
LP-H (12-10-88)	0	0	0	0	1	0	0	0	0	0	0	0
LP-H (12-10-88)	1	0	0	0	1	0	0	0	0	0	0	0
LP-H (12-10-88)	EMPTY											
LP-H (12-10-88)	EMPTY											
LP-H (12-10-88)	EMPTY											

MB - Monkey Bottom marsh; LP - Larchmont Pond marsh. L - low tide; M - mean tide; H - high tide.
Other:
LP-M (12-10-88) - *Crangon* (1)

APPENDIX II

COMPARATIVE BIRD COUNTS IN NATURAL AND MAN-MADE WETLANDS IN NORFOLK, VIRGINIA

Carvel Blair, Ph.D.

Department of Oceanography
Old Dominion University
Norfolk, Va 23529-0276

Chairman
Norfolk Wetlands Board

A study performed for the City of Norfolk Wetlands Board

1 March 1989

COMPARATIVE BIRD COUNTS IN
NATURAL AND MAN-MADE WETLANDS
IN NORFOLK, VIRGINIA

CARVEL BLAIR, Ph.D.

Background

The U. S. Army Corps of Engineers and the Norfolk Wetlands Board, in approving a 1982 U.S.Navy landfill, required compensation for the loss of a wetland covered by dredge spoil. In compliance the Navy created a 2.8 hectare (7 acre) wetland on Norfolk's Willoughby Bay. (Note: One hectare, abbreviated ha, equals 2.5 acres.) It is shown as number 28 in Figure 1 and locally named Monkey Bottom. The policy of requiring wetlands mitigation is controversial, however, since no one knows how soon and to what extent a new marsh becomes the environmental equivalent of the old (USFWS, 1981; Race and Christie, 1982). To investigate this question the City of Norfolk obtained a Coastal Zone Management grant from the National Oceanic and Atmospheric Administration through the Virginia Council on the Environment. Under the grant scientists from Old Dominion University and the Virginia Institute of Marine Science are comparing the new marsh with a similar control marsh in Norfolk's Lafayette River (Big Marsh Island, number 121 in Figure 2). The comparison includes plants, invertebrates, fish, sediments, and birds at both locations. The latter study, reported here, is part of the City's matching contribution.

Procedure

Because of limited resources the bird comparison consisted of only four relatively short counts, one in each location in June and one in January. Both marshes are long and narrow in shape, and the route of each count was a circuit around the wetland. Two observers (including the writer) paddled around Big Marsh Island in a canoe); the writer circled Monkey Bottom on foot. All birds seen in, above, or within about 200 meters of the marsh were listed. Table 1 compares the conditions of the two sites.

Results and Discussion

During the four counts we saw birds of 42 different species (Table 2). Population densities for Big Marsh Island were 21 individuals per ha (8 per acre) in the June count, 15 per ha (6 per acre) in January. For Monkey Botom the densities were 30 per ha (12 per acre)and 12 per ha (5 per acre) for June and January respectively. At both locations the most numerous species in June was the Red-winged Blackbird. House Sparrows were the most numerous at the Lafayette site in January; Ring-billed Gull at Monkey Bottom. There were no surprises; except for the domestic goose and duck all species are either common or abundant in Virginia's Coastal Plain (Kain 1987).

Sixteen species were recorded at both locations (Table

3). At Big Marsh Island we saw 14 species that we did not see at Monkey Bottom. The domestic waterfowl were undoubtedly escapees from waterside homes, and the Canada Goose one of the population that has spread from the nearby zoo. Adjacent suburban yards, trees, and lawns produced the Flicker and perching birds absent from the relatively barren terrain near Monkey Bottom. The other species seen on our count only in the Lafayette occur regularly at Monkey Bottom also; for example three Great Blue Herons were feeding in a pond outside the Monkey Bottom study area at the time of the June count. At Monkey Bottom we saw 14 species not recorded on our Lafayette River count. Most of these also occur regularly along the Lafayette, although the Brown Pelican rarely moves as far upstream as Big Marsh Island. We noted that except for a few Song Sparrows the phragmites stands at Monkey Bottom were almost barren of birdlife. Longer and more detailed observations would probably confirm that the species using both wetlands, and the species diversity at both sites, are nearly identical.

In summary, we found at the two wetlands a rough similarity in population densities and little difference in species assemblages. It thus appears that the man-made marsh and the natural marsh have, five years after establishment, become equally attractive habitats for bird life. For effective wetland compensation it is evidently important that the planting at the new site be very similar to that of the marsh that is being destroyed (i.e. no <u>phragmites</u>). It is also evident that the new marsh must be established in similar terrain if it is to support the same species of birds, and that a period of years will pass before the new habitat matures. With these caveats, our study suggests that from the avian point of view, wetland compensation at Monkey Bottom was a succesful management technique.

Literature Cited

Kain, T., ed.

1987. <u>Virginia's Birdlife</u>: An Annotated Checklist, Virginia Avifauna Number 3, Virginia Society of Ornithology.

Race, M.S. and D.R. Christie

1982. "Coastal Zone Development: Mitigation, Marsh Creation, and Decision Making", <u>Environmental Management</u>, vol. 6, no. 4, p. 317-328.

U.S. Fish and Wildlife Service

1981. "Mitigation Policy", <u>Federal Register</u>, vil. 46, no. 15, p. 7656-7663, 23 Jan. 1981.

COMPARISON OF COUNTS AT MONKEY BOTTOM AND BIG MARSH ISLAND (LAFAYETTE RIVER)

	Monkey Bottom	Lafayette River
Area	2.8 hectares (7 acres)	4.0 hectares (10 acres)
Vegetation	Sa 85%; Sb 5%; Pa 10% plus surrounding fringe	Sa 80%; Sb 10%; Jr 5%; Md 5%
Adjacent terrain	Spoil area to south, highway to north & east open bay to west	River and suburban homes & gardens
June count		
Date	13 June 1989	10 June 1989
Time	9:35 - 11:05 am	7:25 - 8:50 am
Tide	Near high	Near high
Temp	27 deg C (80 deg F)	16 deg C (60 deg F)
Wind	S, 5 m/s (10 kt)	N, 6-8 m/s (12-15 kt)
Sky	Clear	Clear
January count		
Date	26 Jan 1989	25 Jan 1989
Time	11:55 am- 1:10 pm	1:25 pm - 1:55 pm
Tide	Near high	Near high
Temp	17 deg C (63 deg F)	11 deg C (52 deg F)
Wind	SW 4 m/s (8 kt)	NE 8 m/s (15 kt)
Sky	Overcast	Clear

Vegetation key:
- Jr Black Needlerush (*Juncus roemerianus*)
- Md Saltmeadow hay (*Spartina patens*)
- Pa Reedgrass (*Phragmites australis*)
- Sa Saltmarsh Cordgrass (*Spartina alterniflora*)
- Sb Saltbushes (*Iva frutescens* and *Baccharis halimifolia*)

Table 1

BIRDS SEEN ON EACH COUNT
DURING COMPARISON WETLAND STUDY

SPECIES	SCIENTIFIC NAME	LAFAYETTE RIVER		MONKEY BOTTOM	
		JUNE	JANUARY	JUNE	JANUARY
Brown Pelican	Pelecanus occidental			18	
Canada Goose	Branta canadensis	8			
Domestic Goose	Anser cygnoides (?)	1			
Mallard	Anas platyrhnchos	5	3	1	
Domestic Duck	?	1			
Bufflehead	Bucephala islandica		4		
Hooded Merganser	Lophodytes cucullatus				2
American Kestrel	Falco sparverius				1
Great Egret	Casmerodias albus	4		1	
Great Blue Heron	Ardea herodias		2		
Green-backed Heron	Bulorides virescens	2		1	
Yel-crwn Night Heron	Nyctanassa violacea	1		3	
Clapper Rail	Rallus longirostris	1		1	
Kildeer	Charadrius vociferus			1	
Common Snipe *	Gallinago gallinago				1
Great Blackbckd Gull	Larus marinus				1
Herring Gull	Larus argentatus	1		4	4
Ring-billed Gull	Larus delawarensis		6		7
Laughing Gull	Larus atricilla	3		2	
Least Tern	Sterna albifrons	1		1	
Forsters Tern	Sterna forsteri	2			
Royal Tern	Thalasseus maximus			3	
Black Skimmer	Rynchops niger			1	
Rock Dove	Columba livia				5
Mourning Dove	Zenaduria macroura	2	6	4	5
Belted Kingfisher	Megaceryle alcyon		1		
Northern Flicker	Colaptes auratus		1		
Barn Swallow	Hirunda rustica			1	
Purple Martin	Progne subis			3	
Blue Jay	Cyanocitta cristata	1			
American Crow	Corvus brachyrhyncos	7	14	1	
Tufted Titmouse	Parus bicolor	1			
Marsh Wren	Cistothorus palustri	3			
Northrn Mockingbird	Mimus polyghlottos	2			
American Robin	Turdus migratorius	3		1	
European Starling	Sterna vulgaris	1		3	
House Sparrow	Passer domesticus		20		
Redwinged Blackbird	Agelaius phoniceus	27	2	22	1
Common Grackle	Quiscalis quisculs	3		4	
Northern Cardinal	Richmondena cardinal	2			
House Finch	Carpodacus mexicanus			3	
Song Sparrow	Melospiza melodia	1		5	6
Total species	42	83	59	84	33

* probably this species

Table 2

Species Seen at Lafayette River Only

Canada Goose
Domestic Goose
Domestic Duck
Bufflehead
Great Blue Heron
Forsters Tern
Belted Kingfisher
Northern Flicker
Blue Jay
Tufted Titmouse
Marsh Wren
Northern Mockingbird
House Sparrow
Northern Cardinal
Total species 14

Species Seen at Monkey Bottom Only

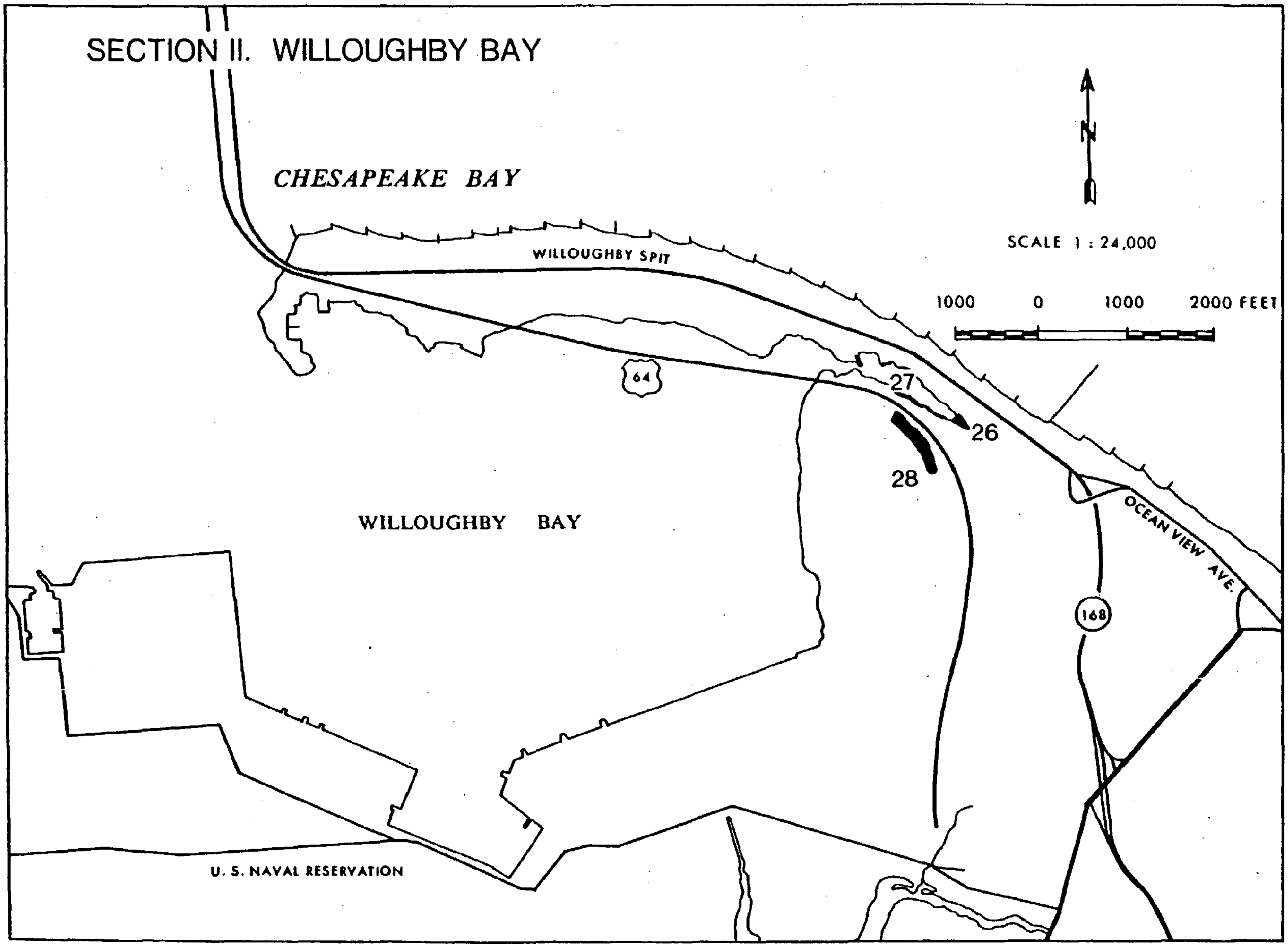
Brown Pelican
Hooded Merganser
American Kestrel
Kildeer
Common Snipe
Great Blackbacked Gull
Royal Tern
Black Skimmer
Rock Dove
Barn Swallow
Purple Martin
House Finch
Total species 12

Species Seen at Both Locations

Mallard
Great Egret
Green-backed Heron
Yellow-crowned Night Heron
Clapper Rail
Herring Gull
Ring-billed Gull
Laughing Gull
Least Tern
Mourning Dove
American Crow
American Robin
European Starling
Redwinged Blackbird
Common Grackle
Song Sparrow

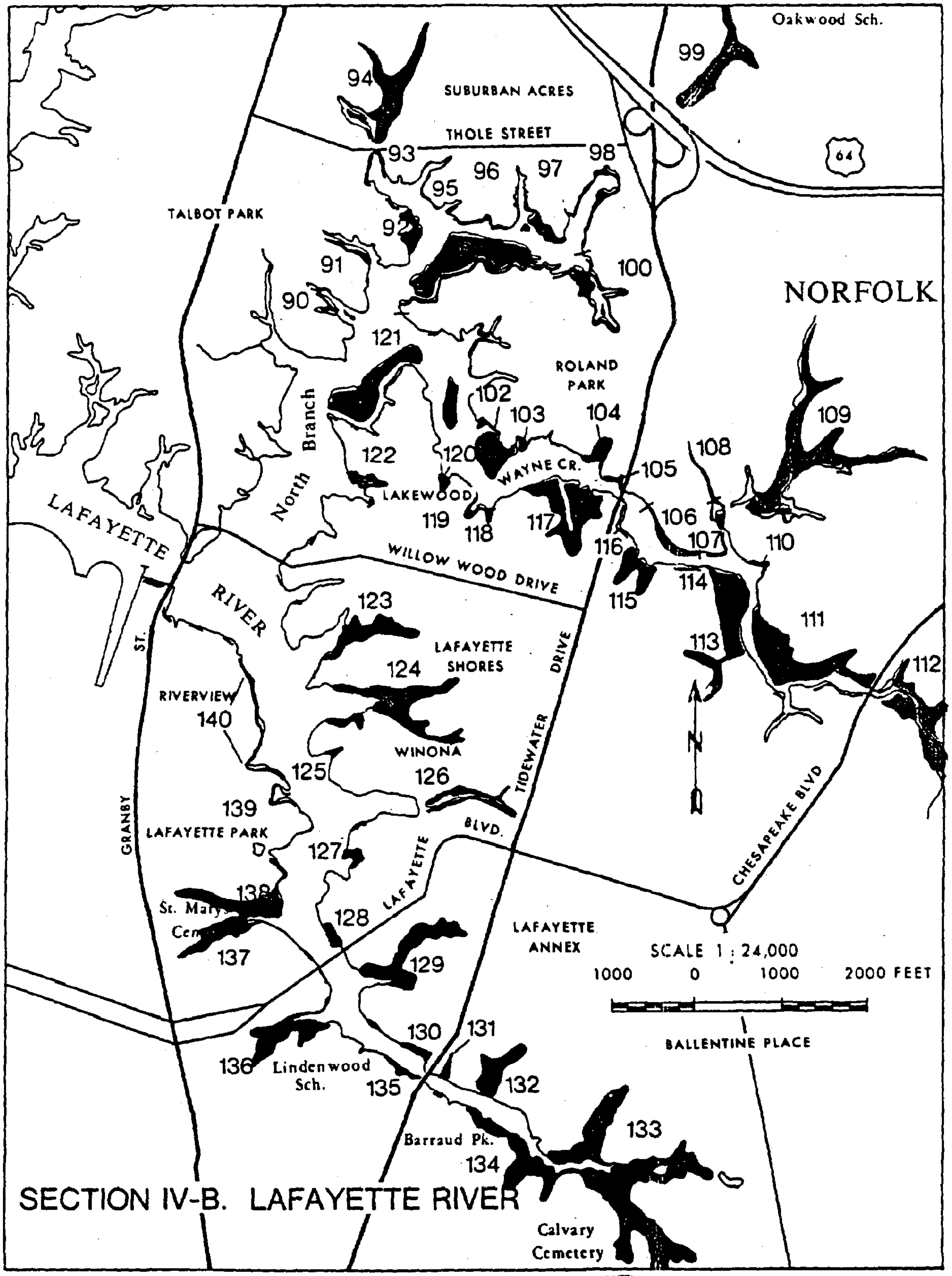
Total species 16

Table 3



Monkey Bottom Location Map
Site No. 28

Figure 1



Big Marsh Island
Location Map
Site No. 121
Figure 2